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Future trends of bioethanol co-production in Serbian sugar plants

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ABSTRACT

Due to the reduction of the economic support for refined sugar efforts have been made to find new ways of using sugar beet outside food industry. This paper investigates the possibilities of introducing bioethanol co-production in Serbian sugar plants. Research shows current state of Serbian sugar industry and technical aspects of bioethanol co-production in sugar plants. These results represent important step toward mass production of bioethanol in Serbian factories. The main goals of introducing the concept of sugar and bioethanol coproduction would be efficient use of available resources for the production of energy, reduction of greenhouse gases emission, decreased dependence on import and creation of new jobs. Besides that, it would provide flexibility in terms of variation of produced quantities of sugar and ethanol, depending on the conditions prevailing on the market.

Contents

1. Introduction

Republic of Serbia covers an area of 88,361 km^2 and its population amounts 7.5 millions according to the 2002 Census. According to Republican Statistical Office 251,497 TJ of energy was imported in 2009 which is 41% of gross inland consumption. Energy security is a quite severe problem in Serbia. The oil import invoice is a serious strain on the country's economy and has been deteriorating the balance of payment situation. The country has become increasingly more dependent on fossil fuels and its energetic security hangs on the fragile supply of imported oil that is subject to disruptions and price volatility [1].Republic of Serbia has focused its development plan to join the European Union and therefore the state government seeks harmonization of laws and legal measures with the directives of the European Union (EU) to promote environmental protection and use of biofuels. The Republic of Serbia ratified the Treaty establishing the Energy Community between the European Union and the Republic of Albania, Republic of Bulgaria, Bosnia and Herzegovina, Republic of Croatia, Former Yugoslav Republic of Macedonia, Republic of Montenegro, Romania, Republic of Serbia and United Nations Interim Mission on Kosovo pursuant to the United Nations Security Council Resolution 1244. Article 20 of this Treaty states that every signatory is obligated to adopt an implementation plan of the Directive 2001/77/EC for the promotion of renewable energy sources derived electric energy production and the 2003/30/EC Directive on the promotion of the use of biofuels or other renewable fuels for transport. Directive 2009/77/EC is the latest document that promotes the use of energy from renewable sources. Binding national targets for the total share of renewable energies in final energy consumption are set based on this Directive, as well as the participation of renewable sources in transport: at least 20% of energy from renewable sources in final energy consumption in the EU and 10% of energy from renewable sources in energy consumption for transport by 2020 year.

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The government has set the targets for energy production from RES and the main goals of biomass policy in Serbia are efficient use of available resources for the production of energy, reduction of greenhouse gases emission, decreased dependence on import and creation of new jobs [2]. Hydropower, biomass, biogas, biofuels, wind power, solar energy and geothermal energy are the major resources to provide Serbia with most of its renewable energy in the future [3]. Liquid biofuels production from renewable resources is one way to reduce both the consumption of crude oil and the environmental pollution [4]. Ethanol, both renewable and environmentally friendly, is believed to be one of the best alternatives, leading to a dramatic increase in its production capacity [5].

In European moderate climate area the most convenient renewable raw materials for bioethanol production are grains and sugar beet [6]. Due to the surplus of sugar on the World Market, the European Union (EU) decided to reduce economic support for refined sugar by about a third, in order to prevent export of excess sugar to non EU-markets [8]. Hinková and Bubník [7], Krajnc and Glavič [8] and Šantek et al. [6] reported that in Czech Republic, Slovenia and Croatia efforts have been made to find new ways of using agricultural products such as sugar beet outside food industry due to the sugar surplus at the local market. Sugar beet is among the plants that give one of the highest carbohydrates yield per hectare. For this reason, it is ideal raw material for the production of ethanol which can be used as a motor fuel [9]. Molasses is by-product of sugar industry and from early days it has been used as raw material for ethanol, baker's yeast and citric acid production [10]. Environmentally friendly technologies are becoming more and more popular because of increased environmental pollution. One of them is the ethanol production process using the fermentation of molasses [11]. In sugar beet processing, molasses is a by-product obtained at the end of the process and the cost of its production is considerably higher than the cost of intermediate products of sugar beet processing. In addition, composition of molasses and intermediates of sugar beet processing depends on number of factors, beet quality and technological process of sugar refining [12]. Hence the optimization of ethanol production from intermediates and byproducts of sugar beet processing in domestic factories is important step toward mass production of ethanol in Serbian factories.

2. Potential of the renewable energy production in the Republic of Serbia

The global energy supply is facing an array of severe challenges in terms of long-term sustainability, fossil fuel reserve exhaustion, global warming and other energy related environmental concerns, geopolitical and military conflicts surrounding oil rich countries, secure supply of energy and fuel price increase [13]. An example of instability in market conditions represents current events in the territory of Libya. According to the International Energy Agency, Libyan oil exports could be off the market for many months due to both war-inflicted damage on oil infrastructure and international sanctions [14]. Diversification of energy sources, agricultural activities and a higher percentage of locally produced energy are goals that can be satisfied by renewable energy production [15].

Since energy shortcomings promise to have serious economic, political and social consequences, energy planning should constitute the most important aspects of overall development planning in developing countries. Renewable energies are an important factor for the strengthening of the regional development [16]. Renewable energy potential in Serbia can cover almost half of its primary energy needs. Utilization of these potentials is currently only 18% [17].

As a country with large areas of agricultural and forested lands, Serbia has strong potential for the production of biomass. Biomass sources represent 63% of the total renewable energy sources (RES) in Serbia (Fig. 1). Arable area per capita amounts 0.65 ha which can be considered favorable. Of the total arable land, 84.4% is in private ownership. However, the average size of private farms is only 2.49 ha. Of the total area suitable for irrigation, only about 2% is irrigated. In addition, events during the period 1991–1999 were negatively impacted in the way of using resources, in terms of their degradation and uncontrolled exploitation, especially land. It can be concluded that Serbia has not taken full advantage of natural resources for agricultural development [18].

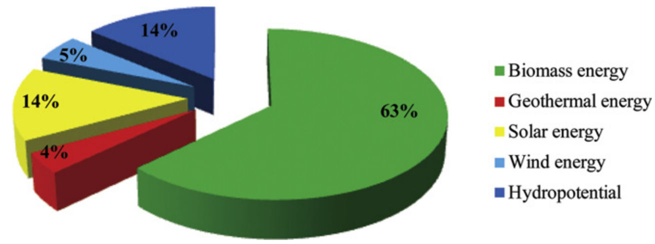

Fig. 1. Potential of renewable energy sources in Republic of Serbia.

Utilization of RES is currently limited to hydropower plants and non-commercial use of biomass and geothermal energy [17]. Waste biomass is utilized from agro complexes for heating purposes in individual rural households while in recent times the use of waste biomass in industry has also been noted. Many steam generators on waste biomass were produced from the industrial process in oil refineries [3].

3. Economic trends and industrial production in the Republic of Serbia

Gross domestic product (GDP) of the Republic of Serbia in the third quarter 2010 recorded a real growth by 2.7% as compared to the same quarter 2009. In this period, the biggest value added growth was realized by the following sectors: financial mediation (8.7%), transport, warehousing and communications (7.4%), ore extracting and quarries (6.2%) and processing industry (5.0%). Contrary to these sectors, the biggest drop in economic activity is recorded in construction industry (−9.2%) and electricity, gas and water production (−4.4%). The biggest gross value added growth for the fourth quarter 2010 was in the sector of transport, warehousing and communications, financial sector, mediation and industrial sector. On the other hand, the biggest gross value added drop was recorded in the following sectors: construction industry, agriculture, hotels and restaurants, state and other services.

Industrial production in the Republic of Serbia in November 2010 recorded a drop by 0.5%, compared to the same month previous year, and compared to the average in 2009 it was higher by 10.3%. Realized growth of cumulative industrial production in the period January–November 2010 recorded a growth by 3.2% compared to the same period 2009. In November 2010, compared to the same month 2009, generation and distribution of electricity, gas and water recorded a drop by 11.4% whereas the ores and stones extraction sector and processing industry sector recorded a growth by 4.0% and 2.1% respectively. Major impact on drop of industrial production in November 2010, compared to the previous year, was made by: production of electricity, production of food stuffs and beverages, production of oil derivates, production of motor vehicles and trailers and production oil derivates, production of basic metals and production of coal.

Total foreign trade in goods in the Republic of Serbia for period January–November 2010 amounted to 23,968.2 million USD, which was an increase by 8.1% compared to the same period previous year. Export of goods reached the value of 8833.0 million USD, which was

higher by 16.3% than in the same period previous year, and import stood at 15,135.2 million USD, which was an increase of 3.9% compared to the same period in 2009. Commodity trade deficit for the 11 months of 2010 amounts to 6302.2 million USD, which means a drop by 9.7% compared to the last year. Coverage of imports by exports was 58.4% and it was higher compared to the same period previous year when it was 52.1%. Most important agrarian products exported in the period January–November 2010 were: yellow maize in the value of 236.7 million USD, sugar from sugar beet, refined, in the value of 162 million USD, raspberry Roland, frozen, in the value of 86.5 million USD, and commercial wheat in the value of 62.4 million USD [19]. Sugar beet integrates agriculture with industry and has an important indirect added value role on many sectors, by providing employment [20].

4. Current state of Serbian sugar industry

The agrarian countryside of Serbia is heterogeneous with fertile fields in the north, low mountains in the central regions and high mountains in the south and southwest with interspersed rolling hills, fertile river valleys and plains. Soil characteristics like fertility and usable field capacity are varying in some regions at a scale that is smaller than rural district scale. Soil ranges from heavy clay over loess to sand and gravel. In the high and low mountain regions, in particular, temperature variance, humidity, precipitation, drainage and natural irrigation via ground and slope water is strongly influenced by regional and local topographic effects, which are mostly unknown or can be extrapolated to larger scales [10]. Sugar beet is cultivated all over Europe under various growing conditions, generally on the more fertile soils. Due to the climatic conditions, yield and quality of sugar beet vary in different European regions [21]. In Serbia sugar beet is cultivated in the most fertile regions and this culture covers 70–80,000 ha (Table 1).

During the transition process toward free economy market sugar industry has been subjected to numerous problems. No new investments in the sugar sector were made at that time. Privatization of the sugar factories in Serbia started in 2001 and it is completed by the 2004 when there is no state ownership in sugar plants. Change of the ownership for sugar industries led to the modernization of existing production capacities by retrofit design and implementation of modern technological processes [10].

There are fifteen sugar factories in the Republic of Serbia. Most of them are located in the Autonomous Province of Vojvodina (Pećinci, Vrbas, Kovačica, Bač, Crvenka, Žabalj, Senta, Sremska Mitrovica, Kovin, Zrenjanin and Nova Crnja), and only four sugar factories are located in Central Serbia (Šabac, Belgrade, Ćuprija and Požarevac). According to the Agency for Business Registers eight factories are in bankruptcy proceedings. All sugar factories in which the production process still runs are located in the Autonomous Province of Vojvodina (Table 2).

Table 1
Sugar beet production in Republic of Serbia [18].

Year	Harvested area (ha)	Production (t)	Yield (t/ha)
2000	44,695	1,070,033	23.9
2001	43,161	1,806,425	41.9
2002	51,906	2,098,080	40.4
2003	64,310	1,738,044	27.0
2004	60,438	2,813,972	46.6
2005	64,326	3,101,176	48.2
2006	71,581	3,188,905	44.5
2007	79,016	3,206,380	40.6
2008	48,028	2,299,773	47.9
2009	61,399	2,797,596	45.6
2010	66,446	3,324,847	50.0

Table 2
Production capacities of sugar factories in the Autonomous Province of Vojvodina.

Sugar factory	Maximum processing capacity of sugar beet (t/a)	Average amount of produced sugar (t/a)
Donji Srem, Pećinci	700,000	100,000
Bačka, Vrbas	700,000	100,000
Jedinstvo, Kovačica	350,000	40,000
Jugozapadna Bačka, Bač	300,000	40,000
Crvenka, Crvenka	600,000	85,000
Šajkaška-Hellenic Sugar Industry, Žabalj	250,000	30,000
TE-TO, Senta	800,000	100,000

The total sugar consumption of sugar in the Republic of Serbia annually amounts about 25–30 kg per capita which is about 240,000 tons of sugar annually on national level. Production capacities of domestic sugar factories are much higher than the consumption of sugar. For this year estimated yield of sugar beet amounts 3,206,919 t and expected sugar production is around 480,000 t. 99% of Serbian sugar export is directed toward the European Union countries and this amount is limited by the existence of a quota of 180,000 t. Hence, there is clear evidence that there is under-utilized capacity in Serbian sugar production.

5. Technical aspects of bioethanol co-production in sugar plants

The increase of sugar production yield and efficiency has led to a reduction in required quantities of sugar beet. The cheaper production of sugar from sugar cane is an additional reason why most of the existing sugar factories in Europe began co-production of ethanol in additionally built refineries [5]. Introducing the concept of sugar and ethanol coproduction is an attractive option for domestic sugar factories, as it provides flexibility in terms of variation of produced quantities of sugar and ethanol, depending on the conditions prevailing on the market. The campaign of sugar beet processing in Serbian sugar factories lasts in average of 70–90 days. Sugar factories are operating at full capacity only during the campaign of sugar beet. With implementing the concept of sugar and ethanol co-production the same plant could work at full capacity throughout the year, which means better utilization of equipment and manpower. In addition, industrial plants for sugar and ethanol co-production have a spatial advantage because of the fact that the raw, thin and thick juice as intermediates and molasses and extracted sugar beet cossettes as byproducts of sugar refining technologies are available in the same place.

Sugar production, which includes the processing of sugar beet to white sugar, extracted sugar beet cossettes and molasses is fully optimized [22]. However, the general situation is changed when sugar beet is considered as a raw material for bioethanol production. Possible patterns of sugar and ethanol production from sugar beet are shown in Fig. 2 [8]. Several years of research are required for defining the optimal configuration for the combined process, in order to find those with improved performance [23]. Selecting the configuration to be applied depends on several factors, such as the selected ratio of sugar and ethanol production, choice of raw material for ethanol production (raw juice, thin juice, thick juice, molasses or extracted sugar beet cossettes), the price of raw materials and products, etc. Upon completion of the sugar beet campaign, for the production of sugar only stored intermediates or byproducts are used. Production of ethanol from sugar beet is technically feasible in most sugar factories, with appropriate modification of the plant and equipment, as well as with some additions. Additional processes and operations required to produce ethanol from

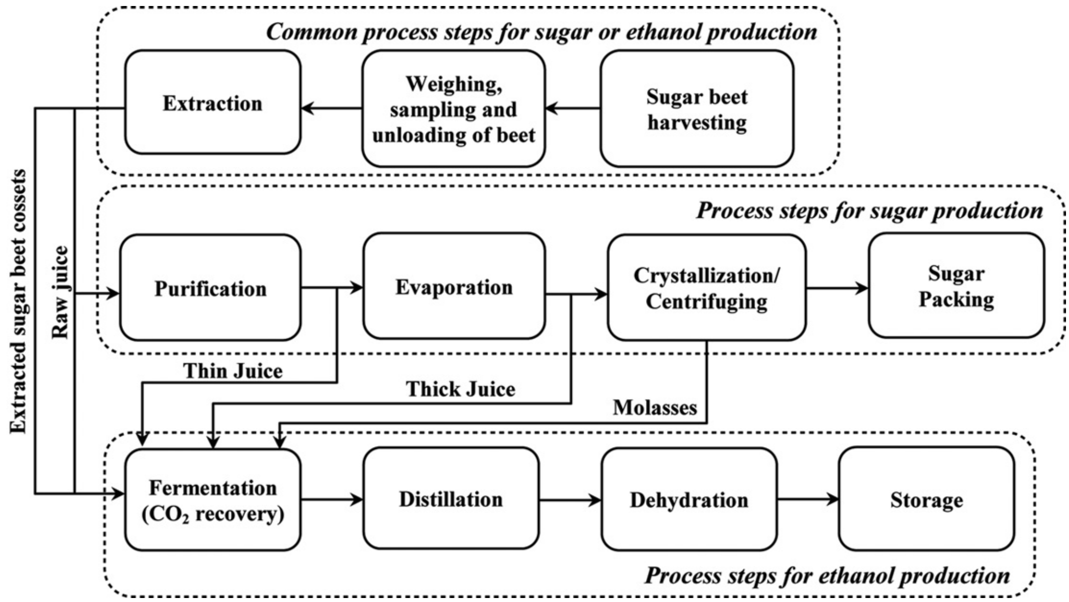

Fig. 2. General unit operations in co-production of sugar and bioethanol from sugar beet.

sugar beet, include fermentation, distillation, dehydration, storage, quality control and packaging of finished product [8].

Preparation of sugar-based raw materials usually involves only dilution, correction of pH value and sterilization. From an economic point of view raw, thin and thick juice and molasses are very suitable raw materials for bioethanol production due to the high content of fermentable sugars, which can be used by yeast as the producing microorganism without any modification [24]. Since the composition of inter- and by-products of sugar refining process depends on the location and type of land where the crop is grown as well as on the applied technological process a need for optimization of the ethanol production by fermentation of these substrates originating from the local sugar factory has arisen [25].

Substrate concentration is an important factor in fermentation. High substrate concentrations inhibit growth and product formation and may distort the metabolism of microorganism. In general, substrate inhibition becomes significant somewhere between in the range 5–25% of sugar with complete inhibition of growth at 40% of glucose [26,27]. For defining the optimal initial sugar content and fermentation duration of media based on raw juice from a domestic sugar factory a desirability function approach was applied, as one of the most widely used methods in science and engineering. Results indicate that the optimal value of fermentation time is in the range of 26–48 h while the optimum initial sugar content varies in the range 9–13% m/v [5]. Accordingly, it can be concluded that the raw juice originating from a domestic sugar factory does not have to be diluted. After adjusting the pH value and sterilization this intermediate can be directly applied as a fermentation medium. The only deficiency that was observed is the appearance of foaming during fermentation. These features, together with a relatively low price compared to other intermediate products from sugar beet processing, make the raw juice a very suitable substrate for bioethanol production [7]. The main deficiency is the impossibility of raw juice storage because the sugar content provides ideal conditions for microbial growth [28].

Thin juice is a very suitable raw material for bioethanol production. Results indicate that the optimal fermentation time of thin juice originating from Serbian sugar refineries is in the range of 38–48 h while the optimum initial sugar content varies in the range 9.5–13% w/v [25]. The problem associated with its implementation is the inability to storage without an applied method of preservation for a longer period of time due to sugar content, which is extremely suitable for microbial growth. For these reasons, it is necessary to achieve a good contact between the sugar factory and the plant for the ethanol production [7].

Preparation of fermentation medium based on thick juice involves the dilution next to the correction of the initial value of pH and sterilization. Since the production of thick juice is very complicated and expensive it significantly affects the price of ethanol produced from this intermediate of sugar beet processing [29].

Molasses with a standard quality can be considered a stable raw material during storage up to a year without evident loss in commercial value [30]. The biggest disadvantage is the fact that molasses is obtained about 4% in relation to processed sugar beet, and that its proceedings is significantly expensive compared to other inter- and by-products of sugar beet processing.

Extracted sugar beet cossettes are by-products of sugar refining technology. They are obtained after extraction of sugar with warm water, and their drying provides the possibility of their storage in the long terms. Extracted sugar beet cossettes represent and addition to animal nutrition. Besides they can be used as fuel or as raw materials for bioethanol production. The conversion of extracted sugar beet cossettes as lignocellulosic feedstock to a form which is suitable for yeast is complicated, expensive and currently represents a major drawback from the perspective of their use in the production of bioethanol [31]. The process of preparation involves pre-treatment in order to break down the structure of lignocellulose materials and make it suitable for enzyme hydrolysis. Pretreatment can be performed by physical, physico-chemical, chemical and biological processes. The next phase is enzymatic or acid hydrolysis in the presence of catalysts which break down hemicellulose and cellulose to fermentable sugars [32].

6. Potential effects of enhanced bioethanol production

The environmental deterioration resulting from the overconsumption of petroleum-derived products, especially transportation fuels, is threatening the sustainability of human society. Ethanol, both renewable and environmentally friendly, is believed to be one of the best alternatives, leading to a dramatic increase in its production capacity [33]. The use of bioethanol as transport fuel has many advantages. The blending of bioethanol with gasoline will reduce the gasoline import and the corresponding import bill. The use of

indigenous fuel guarantees a certain degree of security of energy supply. The addition of bioethanol to petrol enhances the octane value and thereby improves the efficiency of the engine. Bioethanol has a lower vapor pressure than gasoline, which results in lower evaporative emissions. Bioethanol flammability in air is also much lower than that of gasoline, which reduces the number and severity of vehicle fires. Burned in internal combustion engines, bioethanol fuel releases less CO and SO_2 emissions than gasoline and diesel fuels. Bioethanol production from intermediates and byproducts of sugar beet processing will boost employment for domestic population [34].

7. Conclusions

This paper provides valuable information for Serbian sugar plants searching for future development strategies. Implementation of bioethanol co-production in Serbian sugar plants will bring additional revenue to the sugar industry, which is facing threats of price and quota reduction in the preferential markets in the context of trade liberalization. On the other hand, bioethanol can play significant role in satisfying the future energy need in Serbia. Hence, there is strong momentum for bioethanol production expansion in political terms.

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References

[1] Zavargo Z, Popov S, Dodić S, Razmovski R, Tomanović R, Dodić J. Potential of development of bioethanol production and application in Autonomous Province of Vojvodina. Novi Sad: Faculty of Technology; 2008.
[2] Ministry of Energy and Mining of the Republic of Serbia; 2011. Available in: http://www.mem.gov.rs/ [accessed 17.02.2011].
[3] Dodić S, Vučurović D, Popov S, Dodić J, Ranković J. Cleaner bioprocesses for promoting zero-emission biofuels production in Vojvodina. Renew Sustain Energy Rev 2010;14(9):3242–6.
[4] Lang X, Macdonald DG, Hill GA. Recycle bioreactor for bioethanol production from wheat starch II, fermentation and economics. Energy Source: B 2001;23:427–36.
[5] Popov S, Ranković J, Dodić J, Dodić S, Jokić A. Bioethanol production from raw juice as intermediate of sugar beet processing: a response surface methodology approach. Food Technol Biotechnol 2010;48(3):376–83.
[6] Šantek B, Gwehenberger G, Ivančić Šantek M, Narodoslawsky M, Horvat P. Evaluation of energy demand and sustainability of different bioethanol production processes from sugar beet. Resour Conserv Recycl 2010;54:872–7.
[7] Hinková A, Bubník Z. Sugar beet as a raw material for bioethanol production. Czech J Food Sci 2001;19:224–34.
[8] Krajnc D, Glavič P. Assessment of different strategies for the co-production of bioethanol and beet sugar. Chem Eng Res Des 2009;87:1217–31.
[9] van der Poel PW, Schiweck H, Schwartz T. Sugar technology. Berlin: Verlag Dr Bartens KG; 1998.
[10] Jokić A, Zavargo Z, Gyura J, Radivojević S, Šereš Z. An artificial neural network approach to prediction of sugar beet yield and in Serbia. In: Hertsburg CT, editor. Sugar beet crops: growth, fertilization and yield. New York: Nova Science Publisher, Inc.; 2010. p. 153–66.
[11] Krajnc D, Mele M, Glavič P. Improving the economic and environmental performances of the beet sugar industry in Slovenia: increasing fuel efficiency and using by-products for ethanol. J Clean Prod 2007;15(13–14):1240–52.
[12] Vogel M. Alternative utilization of sugar beet pulp. Zuckerindustrie 1991;116:265–70.
[13] Asif M, Muneer T. Energy supply, its demand and security issues for developed and emerging economies. Renew Sustain Energy Rev 2007;11:1388–413.
[14] http://online.wsj.com/article/SB10001424052748704662604576202003885712300.html.
[15] Amigun B, Sigamoney R, von Blottnitz H. Commercialisation of biofuel industry in Africa: a review. Renew Sustain Energy Rev 2008;12:690–711.
[16] Nalan CB, Murat O, Nuri O. Renewable energy market conditions and barriers in Turkey. Renew Sustain Energy Rev 2009;13(6–7):1428–36.
[17] Golusin M, Tesic Z, Ostojic A. The analysis of the renewable energy production sector in Serbia. Novi Sad, Serbia: Faculty of Entrepreneurial Management/Faculty of Technical Sciences; 2010.
[18] Statistical Office of the Republic of Serbia; 2011. Available in: http://webrzs.stat.gov.rs/axd/en/ [accessed 23.02.2011].
[19] Serbian Chamber of Commerce; 2011. Available in: http://www.pks.rs/ [accessed 23.02.2011].
[20] Icoz E, Tugrul KM, Saral A, Icoz E. Research on ethanol production and use from sugar beet in Turkey. Biomass Bioenergy 2009;33:1–7.
[21] Hoffmann CM, Huijbregts T, van Swaaij N, Jansen R. Impact of different environments in Europe on yield and quality of sugar beet genotypes. Eur J Agron 2009;30(1):17–26.
[22] Hempelmann R. Innovative flexible sugar/bioethanol production: the point of view of an equipment supplier. Zuckerindustrie 2007;132(9):698–703.
[23] Cardona AC, Sánchez OJ. Fuel ethanol production: process design trends and integration opportunities. Bioresour Technol 2007;98:2415–57.
[24] Dodić S, Popov S, Dodić J, Ranković J, Zavargo Z, Jevtic Mučibabić R. Bioethanol production from thick juice as intermediate of sugar beet processing. Biomass Bioenergy 2009;33(5):822–7.
[25] Ranković J, Dodić J, Dodić S, Popov S. Bioethanol production from intermediate products of sugar beet processing with different types of *Saccharomyces cerevisiae*. Chem Ind Chem Eng Q 2009;15(1):13–6.
[26] Thatipamala R, Rohani S, Hill GA. Effects of high product and substrate inhibitions on the kinetics and biomass and product yields during ethanol batch fermentations. Biotechnol Bioeng 1992;40:289–97.
[27] Ergun M, Mutlu SF. Application of a statistical technique to the production of ethanol from sugar beet molasses by *Saccharomyces cerevisiae*. Bioresour Technol 2000;73:251–5.
[28] Hinková A, Bubník Z, Šarhova H, Pour V, Kadlec P. Storage of sugar beet raw juice. Czech J Food Sci 2000;18:14–22.
[29] Kunteová L. The potential role of bioethanol. Int Sugar J 1996;98(1173):448–52.
[30] Mantovani G, Vaccari G. Spontaneous decomposition of molasses during storage Part I. Sugar J 1994;96:17–9.
[31] Escobar JC, Lora ES, Venturini OJ, Yáñez EE, Castillo EF, Almazan O. Environment, technology and food security. Renew Sustain Energy Rev 2009;13(6–7):1275–87.
[32] Spagnuolo M, Crecchio C, Pizzigallo MDR, Ruggiero P. Synergistic effects of cellulolytic and pectinolytic enzymes in degrading sugar beet pulp. Bari, Italy: Istituto di Chimica Agraria, Universitgl degli Studi di Bari; 1997.
[33] Bai FW, Anderson WA, Moo-Young M. Ethanol fermentation technologies from sugar and starch feedstocks. Biotechnol Adv 2008;26:89–105.
[34] Dodić S, Popov S, Dodić J, Ranković J, Zavargo Z. Potential contribution of bioethanol fuel to the transport sector of Vojvodina. Renew Sustain Energy Rev 2009;13:2197–200.